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Инновационные технологии в организации контроля производства животноводческой продукции

(✉)**Дыдыкина А.Л., Наконечный А.А., Вязьминов А.О.**
Архангельский научно-исследовательский институт сельского хозяйства – Приморский филиал Федерального исследовательского центра комплексного изучения Арктики им. Н.П. Лавёрова Уральского отделения Российской академии наук
Архангельская область, п. Луговой, Россия
(✉)e-mail: didikina100@yandex.ru

Рассмотрено применение инновационной технологии при контроле молочной продуктивности коров на примере холмогорской породы. Цель исследования – оценить качество молока по массовой доле жира и белка при применении усовершенствованной технологии автоматизации контрольного доения коров холмогорской породы. Использованные методы отбора проб молока и оборудование для его анализа сертифицированы по международным стандартам ICAR (International Committee for Animal Recording). Установлено, что непропорционально отобранные из порций всех доек в течение суток (контрольное доение) средние пробы молока оказывают влияние на величину массовой доли жира и белка, завышая или занижая истинные результаты. Анализ проб от каждого сеанса доения (три пробы – при трехкратном, две – при двукратном доении) проведен с использованием электронной базы количественных и качественных показателей молока, которая создается для перехода на международные стандарты ICAR Архангельской области. Исследования показали, что усовершенствованная технология отбора проб и инновации в определении значений показателей повышают точность, достоверность данных и прогноза молочной продуктивности коров. Доступность для заказчика электронной базы результатов делает работу оперативной. Использование инновационных технологий имеет большой потенциал для улучшения производительности, увеличения эффективности использования ресурсов и повышения качества молока, что обеспечивает продовольственную безопасность и способствует повышению устойчивости сельского хозяйства.

Ключевые слова: контрольное доение, сеанс доения, способ отбора проб молока, автоматизированная система, стандарты ICAR, качество сырого коровьего молока, холмогорская порода коров

Innovative technologies in the organization of livestock production control

(✉)**Dydykina A.L., Nakonechny A.A., Vyazminov A.O.**
Arkhangelsk Research Institute of Agriculture – Primorsky branch of the N. Laverov Federal Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences
Lugovoi, Arkhangelsk region, Russia
(✉)e-mail: didikina100@yandex.ru

The application of innovative technology in the control of milk productivity of cows on the example of the Kholmogor breed is considered. The purpose of the research is to evaluate the quality of milk by mass fraction of fat and protein at application of the improved technology of control milking automation of the Kholmogor cows. The used methods of milk sampling and equipment for its analysis are certified according to ICAR (International Committee for Animal Recording) international standards. Average milk samples taken disproportionately from all milking portions during the day (control milking) were found to affect the mass fraction of fat and protein by overestimating or underestimating the true results. Analysis of the samples from each milking session (three samples – at threefold milking, two – at twofold milking) was carried out using the electronic database of quantitative and qualitative indicators of milk, which is being created for the transition to the international ICAR standards of the Arkhangelsk region. The studies have shown that improved sampling technology and innovations in determining indicator values increase the accuracy, reliability of data and prediction of cow milk productivity. The availability to the customer of an electronic database of

results makes the work operational. The use of innovative technologies has great potential to improve productivity, increase resource efficiency and improve milk quality, thereby ensuring food security and contributing to agricultural sustainability.

Keywords: control milking, milking session, method of milk sampling, automated system, ICAR standards, quality of raw cow's milk, Kholmogor breed of cows

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INTRODUCTION

Introduction of innovative technologies in agriculture can increase production efficiency, reduce production time and improve the quality of products, as well as increase their competitiveness [1–4].

According to Rosstat, Russia produced 5.7 million tons of milk in 2022, which is 2.4% higher than in 2021. Among agricultural producers of the Arkhangelsk region there is also a tendency to increase milk productivity of cattle. Especially it can be traced in livestock breeding farms. There is also an increase in cow productivity in the agricultural organizations of the region by 6.6% over the ten-year period. Milk yield per cow amounted to 8505 kg. The total number of cattle in the farms of the Arkhangelsk region of all categories amounted to 39 600, including 18 400 cows. The cows of the Kholmogor cattle breed with 0% blood of improving (Holstein) breed in their genotype are considered as gene pool cows, and the animals with no more than 75% of Holstein blood in their genotype are considered as pedigree cows. The farms with predominance of such animals have the status of breeding the gene pool (Kholmogor) breed. The farms with commercial herds, where the bloodline of pedigree animals is more than 76% on the Holstein breed, acquire the status of breeding Holstein breed of cattle[1, 2].

In modern conditions of breeding work with dairy cattle breeds, it is extremely important to have highly reliable indicators of primary breeding records, and the recognition of domestic breeding products (in this case, the Kholmogor breed) in the international market will make it possible to sell them not only in Russia, but also abroad [5-7]. In this regard, in our country there is a need to create such a system of breeding animal registration, which would provide reli-

[1]FSIAS PR (Federal State Information and Analytical System of Pedigree Resources). URL: https://www.tadviser.ru/index.php/Product: FSIAS _ PR _(Federal _state_information-analytical_system_of pedigree_resources) (accessed on 15.03.2024).

[2]Methodical recommendations on conducting breed inventory of breeding stock of dairy production cattle. URL: https://mcx.gov.ru/upload/iblock/b07/b07ebe9f3a072f2fc93b950302c0ec96.pdf (accessed on 15.03.2024).

able identification and registration of breeding value both for on-farm use and for the purposes of international breeding cooperation. To solve this problem, it is necessary to use modern technology of herd record keeping and registration, based on a set of methods, including automated and software tools[3] [8–10].

At the moment in Russia there are two orders of the Ministry of Agriculture of Russia: No. 25 of February 1, 2011 (registration rules) and No. 379 of October 28, 2010 (conducting valuation), which regulate the organization of registration of quantitative and qualitative characteristics of milk from the controlled herd of cows, but there is no clear methodology for the formation of a daily milk sample for physical and chemical analysis.

Since 1984 ICAR (International Committee for Animal Recording) has been developing rules, standards and recommendations for testing, approval and periodic inspection of milk recording devices. Recommendations have also been developed concerning methods for determining fat, protein, lactose, urea and somatic cell counts in each milk sample individually from each animal.

Milk recording and quality control methods should be internationally standardized reference methods (e.g. ISO, IDF, AOAC methods). Only devices that comply with ISO 3918 standards are acceptable for milk recording purposes.

Milk collected from each animal during control milking using devices that meet the above requirements must be tested by the appropriate laboratories. As of March 2017, ICAR offers the option to certify milk analyzers in accordance with the ICAR "Milk Analyzer Evaluation Protocol" developed and approved by the ICAR Milk Analysis Subcommittee[4].

The use of milk metering and selection devices, as well as extended analysis of milk quality by many parameters using high-precision equipment certified by ICAR, has begun to be applied in farms of the Arkhangelsk region engaged in cattle breeding since 2017. The initiator of the implementation of these innovative technologies is the Primorsky branch of the Federal Research Center for Integrated Arctic Research of the Ural Branch of the Russian Academy of Sciences – Arkhangelsk Research Institute of Agriculture (ArkhNIISKh). The laboratory for selection control of milk quality, established on the basis of the Institute, with certified equipment for advanced milk analysis by Bently, provides an opportunity for milk producing enterprises to obtain accurate data on its composition. The laboratory periodically verifies the accuracy of the instruments through individual external inspection and by comparing routine analysis methods with reference samples supplied by equipment manufacturers.

In modern conditions, the introduction of innovative technologies in agriculture is closely related to digitalization, which has become widespread in the Russian Federation. The realization of the project "Digital Agriculture" in Russia is one of the most promising economic directions with the use of new technologies and intelligent solutions. This project includes the introduction of innovative solutions and the development of the platforms that will help agricultural producers to improve the management of their resources and make better decisions based on promptly obtained accurate data[5]. In particular, it concerns the system of feeding rations, control over the quality characteristics of milk. Currently, agricultural producers have access to their animals through special platforms, where they can get preliminary information about the quality of their products, general state of animal health, productivity, etc.

The purpose of the research is to improve the technological process of selection control of milk quality for a more accurate assessment of the breeding value of animals.

[3] *Trukhachev V.I., Atanov I.V., Kapustin I.V., Gritsai D.I.* Digital technologies, automated systems and robots in animal husbandry // Textbook, 2nd edition. St. Petersburg, Publishing House "Lan", 2023, 104 p.

[4] The global standard for livestock data. URL: https://www.icar.org/ (accessed on 16.03.2024).

[5] Departmental project "Digital Agriculture". URL: https://mcx.gov.ru/upload/iblock/900/900863fae06c026826a9ee43e124d058.pdf (accessed on 10.03.2024).

In order to achieve the goal, the following tasks have been set:

– analyze milk productivity of the Kholmogor cows at 2-, 3- and 4-fold milking with milk sampling from each milking session in a separate test container;

– determine the values of milk quality parameters from each milking session on the Bentley Instruments DairySpec Combi analytical system;

– perform comparative analysis of the results of control milkings.

The novelty of the research consisted in the proposal of a sampling method certified according to ICAR requirements, based on the analysis of qualitative indicators of milk from each milking session during control milkings, to obtain reliable selection indicators taking into account the characteristics of the Kholmogor breed cows.

MATERIAL AND METHODS

The studies were conducted in the Arkhangelsk region in the conditions of year-round tie-up housing of cows of the Kholmogor breed, receiving portion feeding at 2-, 3-, 4-days milking.

Milk productivity of cows was counted according to the results of control milkings. During the record day at each milking session individual accounting of quantitative and qualitative milk parameters was provided: mass fraction of fat (MFF, %) and mass fraction of protein (MFP, %). Individual meters of Tru-Test company (New Zealand) were used, which were equipped with a measuring cup, providing individual milk recording for one milking session up to 33 kg. The system of milk sampling is certified by ICAR, which allows obtaining internationally recognized results in breeding farms. Further, individual control milk samples were taken from each milking session in a special test container with a certified preservative in the amount of 40 ml for laboratory tests on milk quality parameters in the controlled animals.

Bentley Instruments' Bentley DairySpec Combi 150 model combined analytical system was used for selective milk quality control, which has ICAR certification according to ISO/IDR standards.

The permissible threshold of reliability of the results of each control milking on the content of fat and protein in milk was determined on the basis of establishing standard deviations of record indicators. The composition and physicochemical properties of milk were studied in accordance with the requirements of the Technical Regulations of the Customs Union "On the safety of milk and dairy products" (TR CU 033/2013)[6].

The results of experimental studies were processed using popular methods of mathematical statistics and Microsoft Office Excel package of mathematical programs for computing machines, as well as according to the manual on biometrics for zootechnicians[7].

Thanks to the results obtained, a unified regional database has been created, which contains information on quantitative and qualitative indicators of dairy products and is used to assess the breeding value of dairy herds being formed.

RESULTS AND DISCUSSION

In the process of research, milk samples were taken from cows in OOO "Agrofirma Kholmogorskaya" of the Arkhangelsk region, which are milked twice a day, in AO "Kholmogorsky Plemzavod" – three times a day and in APC "Nikolsk" – on four times a day milking. All data of qualitative analysis of milk obtained during control milking of cows were recognized as reliable.

Results of researches show that milk yield at fourfold milking made 24,7 kg, at threefold –

[6]Technical Regulations of the Customs Union " On safety of milk and dairy products " (TR CU 033/2013) (as amended through December 19, 2019). URL: http://docs.cntd.ru/document/499050562 (accessed on 19.03.2024).

[7]*Plokhinsky N.A.* Manual on biometrics for zootechnicians. Moscow: Kolos, 1969, 256 p.

28,8 kg, at twofold – 19,3 kg and had significant differences on quantity of milk received in each session of milking. Thus, at fourfold milking from the first to the fourth session the distribution by sessions was – 44, 16, 19 and 21%, respectively, at twofold milking approximately the same – 49.7 and 50.3%, at threefold milking – 49, 26 and 25%, respectively (see Fig. 1–3).

The analysis showed that the deviations of the specific weight of milk from the total daily milk yield obtained for the morning milking session from controlled cows ranged from 12 to 75%, for the afternoon session from 9 to 50% and for the evening session from 10 to 88%.

The table presents the experimental data on the qualitative composition of milk, which show changes in the values of indicators for mass fraction of fat in the range of 2.67–4.85% and for mass fraction of protein – 2.89–3.16%, respectively.

In the course of the study, it was found that at milking 3 times a day with a total milk yield of 28.8 ± 0.41 kg, milk quality parameters of the Kholmogor cows (in terms of 1% of milk) were very high for MFF (3.95 ± 0.05%) and significantly lower for MFP (3.06 ± 0.01%) compared to the breed standard (3.30%). At the same time, it was significantly ($P > 0.999$) found that milk obtained during day milking was characterized by the highest fat content (4.85 ± 0.06), which was significantly higher than the fat content of milk during morning and evening milking by 1.49 and 0.71%, respectively. It was also found that the mean milk protein content for the afternoon milking was 0.03% (at $P > 0.95$) lower than the mean for the morning milking and 0.08% (at $P > 0.999$) lower than the mean for the evening milking.

In case of double milking, no significant fluctuations in MFF and MFP between sessions were revealed. Cows milked 4 times a day showed the most significant fluctuations in milk quality parameters. Thus, at morning milking the percentage of fat in milk amounted to 2.67%, at afternoon milking it was 4.56%. On the contrary, in the afternoon the protein content

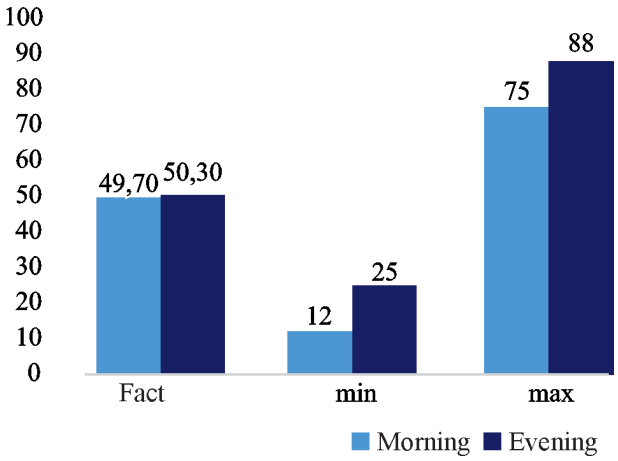

Рис. 1. Суточные удои коров при двукратном доении ($n = 3627$), %

Fig. 1. Daily milk yield of cows with twofold milking ($n = 3627$), %

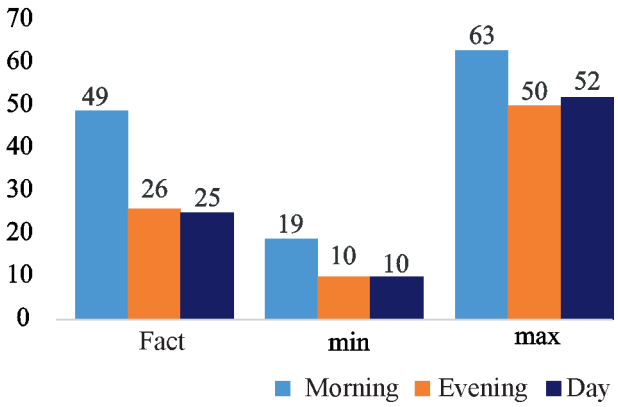

Рис. 2. Суточные удои коров при трехкратном доении ($n = 4025$), %

Fig. 2. Daily milk yield of cows with threefold milking ($n = 4025$), %

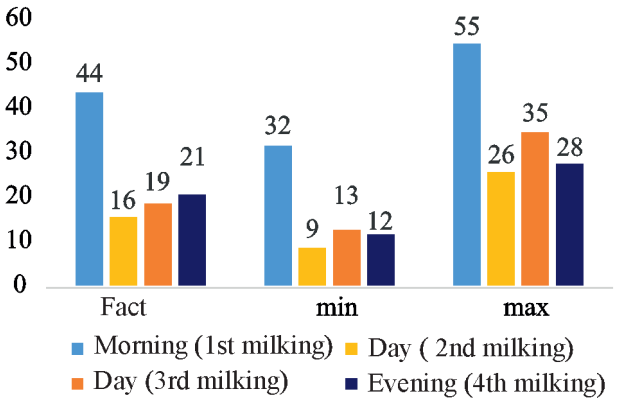

Рис. 3. Суточные удои коров при четырехкратном доении ($n = 67$), %

Fig. 3. Daily milk yield of cows with fourfold milking ($n = 67$), %

Количественный и качественный состав молока по сеансам доения
Quantitative and qualitative composition of milk by milking sessions

Milking session	Quantity of milk yield, kg	Content	
		fat, %	protein, %
Two milking sessions			
Morning	9,50 ± 0,06	3,63 ± 0,01***	3,16 ± 0,01***
Evening	9,63 ± 0,06	3,60 ± 0,01***	3,13 ± 0,01***
In a 24-hour period	19,13 ± 0,12	3,61 ± 0,01	3,14 ± 0,01
Three milking sessions			
Morning	14,1 ± 0,20	3,36 ± 0,07***	3,05 ± 0,01*
Afternoon	7,5 ± 0,15	4,85 ± 0,06	3,02 ± 0,01
Evening	7,2 ± 0,15	4,14 ± 0,05***	3,10 ± 0,01***
In a 24-hour period	28,8 ± 0,41	3,95 ± 0,05	3,06 ± 0,01
Four milking sessions			
Morning	10,84 ± 0,30	2,67 ± 0,07***	3,07 ± 0,04***
Afternoon	3,96 ± 0,14	4,56 ± 0,11***	2,89 ± 0,03***
Afternoon	4,68 ± 0,16	3,99 ± 0,08	3,01 ± 0,04
Evening	5,25 ± 0,17	3,42 ± 0,08***	3,11 ± 0,04***
In a 24-hour period	24,74 ± 0,65	3,38 ± 0,06	3,04 ± 0,03

Note. Confidence limits: *at $P > 0,95$, **at $P > 0,99$, ***at $P > 0,999$.

in milk was minimal at 2.89% and maximum at evening milking – 3,11%.

The obtained experimental data show how great is the variation of milk quality characteristics by milking sessions and depending on its multiplicity.

According to the requirements for the reliability of the results of cow milking control in the conditions of breeding farms of the Arkhangelsk region, the researchers of the ArkhNIISKh and OOO RC "Plinor" have developed and implemented an automated system to record the productivity of cows and determine the food safety of raw milk as a raw material for its industrial processing.

The system allows to automate the process of milk productivity and milk quality recording with the help of processing information from the Bentley analytical system, as well as when using mobile devices for control milking. The automated system processes information from the devices in real time, which makes it possible to automatically monitor the dynamics of cow productivity. The improved system is based on individual recording of both quantitative and qualitative indicators of milk for each milking session of a cow for a full control day and automated recalculation of qualitative indicators for seven positions through one-percent milk (see Fig. 4).

The advantages of the automated system of selection control of milk quality using mobile and WEB-applications, integrated with the software for breeding and registered in the register of Russian programs for computers and databases in the Ministry of Communications of the Russian Federation, also include the use of individual recording of quantitative and qualitative indicators of milk. It is performed for each milking session in a separate test container equipped with an RFID tag, which is read by a barcode scanner of the analytical system Bentley DairySpec Combi.

This results in the provision of:

– exchange of documents via Internet between the analytical laboratory and customer farms;

– reducing the influence of human factor on the reliability of the obtained results of control milking of cows;

– detection of animal diseases at early stages of their development and control of their condition by biochemical parameters of milk (ketoses, acidoses, mammitises);

– control of nutrition adequacy of dairy cows;

– increase in the number of automated record-keeping operations;

– automation of data collection and exchange;

– increasing the efficiency of work on primary zootechnical record keeping.

In the near future, an electronic database of highly reliable data will be formed for the conditions of the Arkhangelsk region in order to further develop the algorithms of conversion factors for the transition to a single sampling of milk for the accounting day, according to the international recording system ICAR. This will contribute to improving the economic efficiency of dairy cattle breeding in the region by making management decisions on the basis of reliable information on milk productivity of lactating cows and confirmed pedigree value of the bulls being used.

CONCLUSION

Improvement of the technological process of selection control of milk quality allowed revealing the following:

– in controlled cows in milking sessions, deviations of specific milk weight from total daily milk yield were established: for morning milking session – from 12 to 75%, for afternoon milking session – from 9 to 50% and for evening milking session – от 10 до 88%;

– no significant fluctuations in the mass fraction of fat and mass fraction of protein between sessions were observed during double milking of the Kholmogor cows;

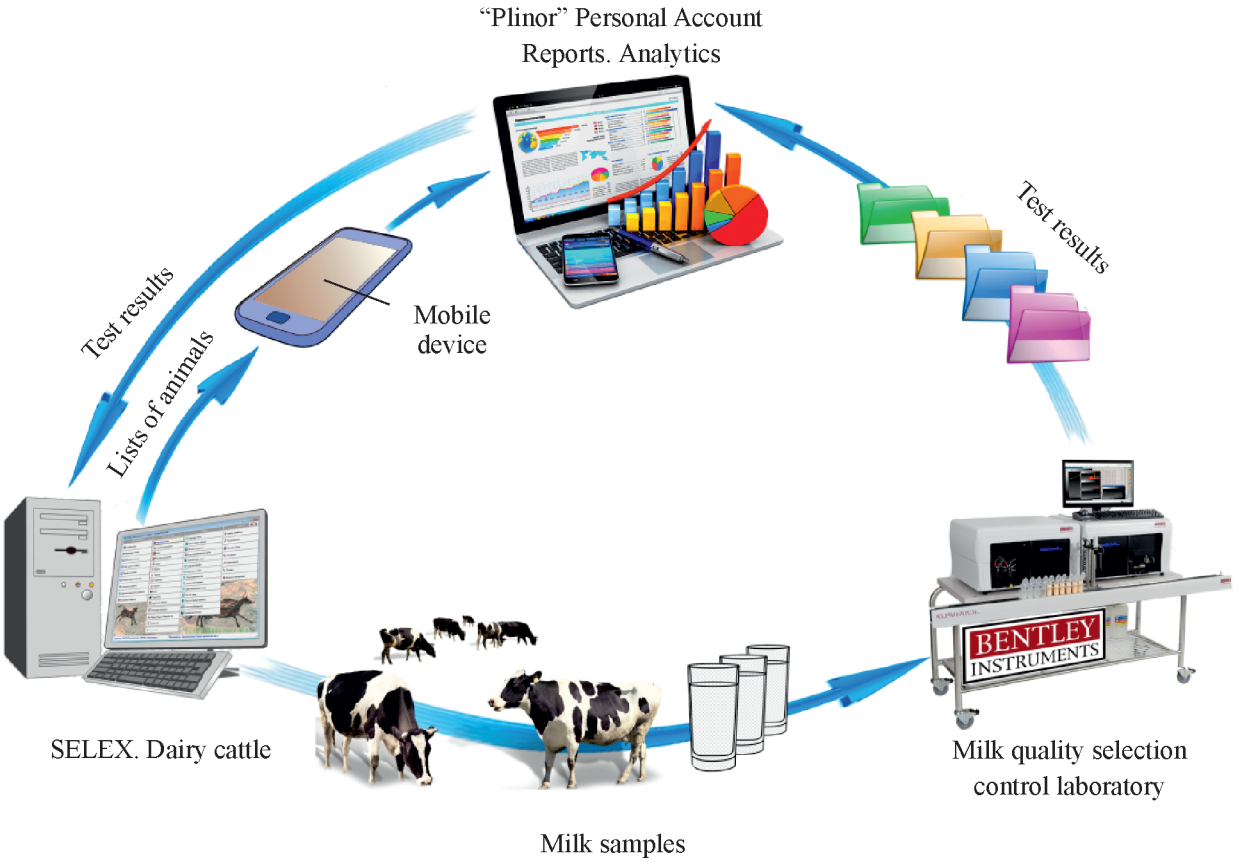

Рис. 4. Схема автоматизированной системы учета

Fig. 4. The scheme of the automated accounting system

– at three times milking with a total milk yield of 28.8 ± 0.41 kg with a mass fraction of fat (in terms of 1% of milk) of 3.95 ± 0.05% between sessions, differences were found: milk obtained during day milking was characterized by a higher fat content (4.85 ± 0.06%) than during morning and evening milking, by 1.49 and 0.71%, respectively.

Thus, the use of innovative technologies provides greater potential for assessing the breeding value of cows, increasing productivity, improving milk quality and improving the efficiency of utilization of available resources in agriculture.

It is important to continue research in this area and invest in technology development to increase agricultural sustainability and ensure food security for our nation's people.

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ИНФОРМАЦИЯ ОБ АВТОРАХ

✉ **Дыдыкина А.Л.,** старший научный сотрудник; **адрес для переписки:** Россия, 163000, Архангельская область, Приморский район, п. Луговой, 10; e-mail: didikina100@yandex.ru

Наконечный А.А., старший научный сотрудник

Вязьминов А.О., ведущий инженер

AUTHOR INFORMATION

✉ **Alexandra L. Dydykina,** Senior Researcher; **address:** 10, Lugovoi, Primorsky District, Arkhangelsk Region, 163000, Russia; e-mail: didikina100@yandex.ru

Alexander A. Nakonechny, Senior Researcher

Andrey O. Vyazminov, Leading Engineer

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